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NOTE

# Altitudinal and latitudinal variations of sodium 5893Å night airglow intensity

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**Abstract** : In this Note, the variations of sodium 5893Å night airglow line intensity with altitude and latitude are presented The volume emission rate of the line is calculated and an empirical relation between volume emission rate and height is obtained. The calculated intensity of the line agrees with the accepted value The latitudinal variation of 5893Å line emission is explained after considering latitudinal variation of average air density as obtained by Jacchia

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The main excitation mechanism for the emission of 5893Å line during night is given by

$$NaO^* + O \xrightarrow{k_1} Na(^2P) + O_2$$

$$Na(^2P) \longrightarrow Na(^2S) + h\nu \ (5893Å)$$

$NaO^*$ is produced by the following reactions :

$$\text{I.} \quad Na + O + M \xrightarrow{k_2} NaO^* + M$$

$$\text{II.} \quad Na + O_2 + M \xrightarrow{k_3} NaO_2 + M$$

$$NaO_2 + O \xrightarrow{k_4} NaO^* + O_2$$

$$\text{III.} \quad Na + O_3 \xrightarrow{k_5} NaO^* + O_2$$

where $k_1 = 4 \times 10^{-11}\,cm^3\,s^{-1}$, $k_2 = 7 \times 10^{-33}\,cm^6\,s^{-1}$

$k_3 = 2 \times 10^{-33}\,cm^6\,s^{-1}$, $k_4 = 1 \times 10^{-11}\,cm^3\,s^{-1}$

$k_5 = 6.5 \times 10^{-12}\,cm^3\,s^{-1}$.

In a previous paper [1], it was shown that the volume emission rate of NaO* produced by reaction III is greater than those by reactions I and II ( Ghosh and Midya, 1986). Neglecting the contributions of I and II, the volume emission rate of NaO* from reaction III becomes

$$Q_{NaO^*} = k_5\, n(Na)\, n(O_3)$$

Hence

$$Q_{Na^*} = k_1 n\left(NaO^*\right) n(O)$$
$$= k_1 k_5\, n(O)\, n(Na)\, n(O_3). \tag{1}$$

Using number densities of Na, O and $O_3$ given in Table 1, the volume emission rate of 5893Å line at different heights at night is calculated and is shown in Figure 1. The night-time $n$(Na)

**Table 1.** Volume emission rates of 5893A line emission of sodium at different heights.

| Altitude (km) | Number density (atoms/c c) $n(Na) \times 10^{-3}$ | $n(O_3) \times 10^{-7}$ | $n(O) \times 10^{-11}$ | Volume emission rate $Q_{5893}$ ($cm^{-3}\ sec^{-1}$) |
|---|---|---|---|---|
| 85 | 1.0 | 10 | 1.0 | 2.6 |
| 86 | 1.4 | 10.2 | 1.29 | 4.76 |
| 87 | 1.8 | 10.4 | 1.58 | 7.69 |
| 88 | 2.2 | 10.6 | 1.87 | 11.34 |
| 89 | 2.6 | 10.8 | 2.16 | 16.18 |
| 90 | 3.0 | 11.0 | 2.45 | 21.02 |
| 91 | 3.5 | 8.5 | 2.99 | 23.12 |
| 92 | 4.0 | 6.0 | 3.52 | 2[illegible].96 |
| 93 | 3.6 | 5.0 | 3.98 | 18.63 |
| 94 | 3.3 | 4.0 | 4.43 | 15.07 |
| 95 | 3.1 | 3.0 | 4.54 | 10.98 |
| 96 | 2.7 | 2.7 | 4.85 | 9.19 |
| 97 | 2.3 | 2.4 | 4.86 | 6.9 |
| 98 | 1.8 | 2.1 | 4.88 | 4.79 |
| 99 | 1.4 | 1.8 | 4.76 | 3.21 |
| 100 | 0.9 | 1.5 | 4.63 | 1.63 |

is taken from Gibson and Sandford [2]. $n(O_3)$ and $n$(O) are taken from Karassovasky [3] and Jacchia [4] respectively. For the theoretical curve an empirical equation is fitted having the form

$$Q_{5893} = k \exp\left[-b(h-91)^2\right]$$

where $Q_{5893}$ = Volume emission rate of 5893Å line at night,

$h$ = height in km,

$k, b$ = constants of the curve.

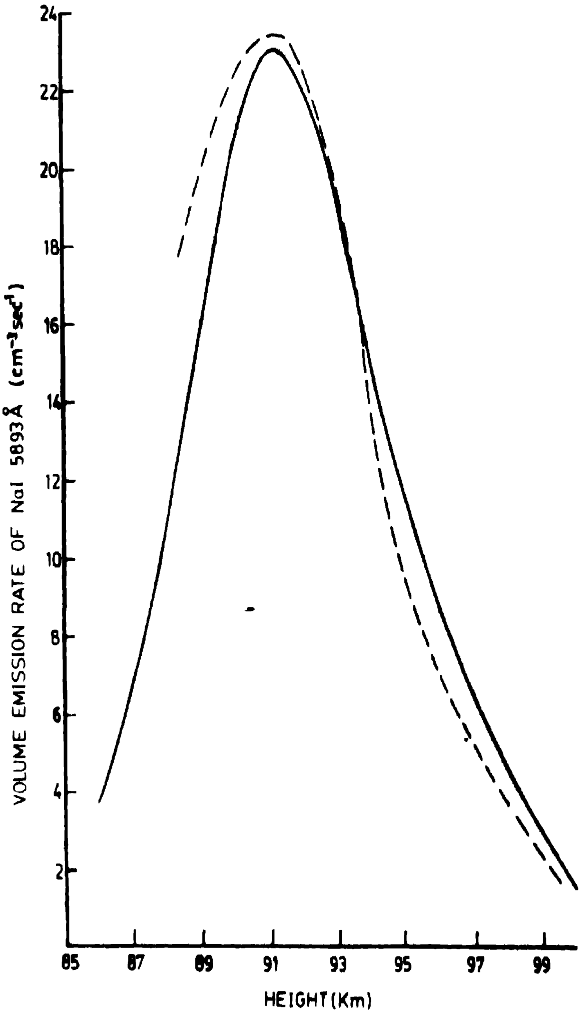


**Figure 1.** Altitude distribution of volume emission rate of sodium 5893Å line emission. The dashed curve is theoretical, the full line currve is cmputed from experimental data.

From analysis it is found that $k$ = 17.89 and $b$ = 0.0316. The curve obtained from eq (2) fits fairly well with the theoretical curve.

The latitudinal variation of 5893Å line intensity of night airglow was carried out by various investigators [5,6]. Davis and Smith [5] reported latitudinal intensity variation of this line from observations for 7 months on Eltanin voyage (Figure 2). The curve shows minimum intensity around geographic equator and then increases on either side of it. Weins

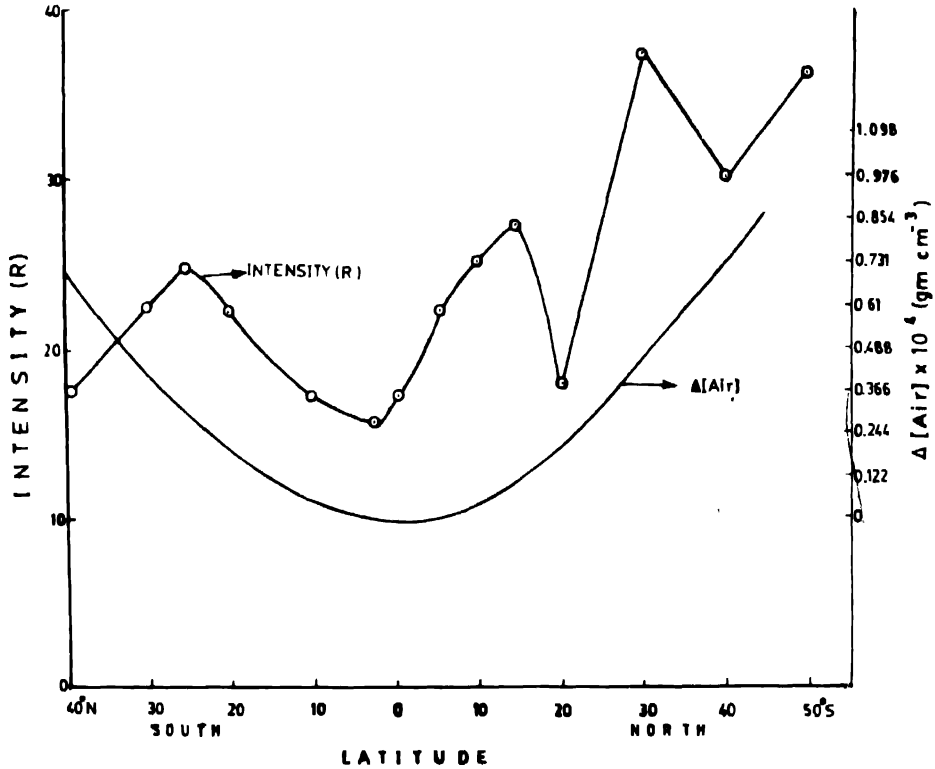


**Figure 2.** Latitudinal variations of $\Delta$[Air] and 5893A line emission.

and Weill [6] reported the same type of latitudinal intensity variation of this line and suggested that the observations are masked by seasonal effect. It may be mentioned that the authors have already explained the latitudinal variation of 5577A line taking into consideration Jacchia's Model [7].

The intensity I of 5893Å line becomes

$$I = \int^{\infty} Q_{5893} dh$$

where,

$$Q_{5893} = k_1 k_5 \, n(O_3) \, n(O) \, n(Na) \quad \text{(from eq.1)}.$$

In the mixed atmospheric region, the number density of different constituents is proportional to the average air density.

Hence,

$$Q_{5893} = p[\text{Air}]^3.$$

Considering variation of air density,

$$Q'_{5893} = p\{[\text{Air}] + \Delta[\text{Air}]\}^3.$$

Neglecting terms containing higher powers of $\Delta[\text{Air}]$, we obtain,

$$Q'_{5893} - Q_{5893} = 3p[\text{Air}]^2\ \Delta[\text{Air}]$$

$$\therefore\ Q \propto \Delta[\text{Air}].$$

The latitudinal variation in the log of air density as given by Jacchia [4] is

$$\text{Log}\{\Delta(\text{Air})\} = \frac{\phi}{|\phi|} s\, p \sin^2\phi,$$

where, $\phi$ = geographical latitude,

$S = 0.014\,(z-91)\exp\{-0.0013\,(z-91)^2\}$,

$p = \sin(2\pi\psi + 1.72)$, where $\psi$ represents fraction of a year and is given by

$$\psi = \frac{t - \text{Jan } 1}{365} \cdot (t \text{ in days}).$$

From the above empirical relations, the latitudinal variation of average air density is obtained at $Z = 92$ Km and the results are given in Table 2.

**Table 2.** Parameters calculated from Jacchia's relations.

$Z = 92$ km $S = 0.0014$ $P = 0.1303$ $t = 336$ days (Dec 2)

| North lat | $\Delta[\text{Air}] \times 10^4$ (gm cm$^{-3}$) | South lat. | $\Delta[\text{Air}] \times 10^4$ (gm cm$^{-3}$) |
|---|---|---|---|
| 0 | 0.000 | 0 | 0.000 |
| 5 | 0.014 | 5 | 0.014 |
| 10 | 0.055 | 10 | 0.055 |
| 15 | 0.122 | 15 | 0.122 |
| 20 | 0.213 | 20 | 0.213 |
| 25 | 0 326 | 25 | 0.326 |
| 30 | 0 456 | 30 | 0.456 |
| 35 | 0.600 | 35 | 0.600 |
| 40 | 0.754 | 40 | 0.754 |
| 45 | 0.912 | 45 | 0.912 |
| 50 | 1 070 | 50 | 1.070 |
| 55 | 1.224 | 55 | 1.224 |
| 60 | 1.368 | 60 | 1.368 |

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